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Abstract: Online video has become established as a fundamental part of the fabric of the web; widely used by people for information sharing, learning and entertainment. We report results from a design study that explored how people interact to create shared multi-path video representations in a social video environment. The participants created multiple versions of a video by providing alternative and interchangeable scenes that formed different paths through the video content. This multi-path video approach was designed to circumvent limitations of traditionally linear video for use as a shared representation in collaborative knowledge building activities. The article describes how people created video resources in collaborative activities in two different settings. We discuss different modes of working that were observed and outline the specific challenges of using the video medium as shared representation. Finally we demonstrate how an analysis of collaborative dimensions of the shared multi-path video representation can be applied to discuss the design space and to raise the discourse about the usefulness of these representations in knowledge building environments.

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London 16th September 2011

Dear Editors and Reviewers,

We'd like to thank the reviewers for their time and effort in reading and providing recommendations for our submission. We have attempted to address most of the reviewers concerns in our resubmission. We hope they go some way towards satisfying them.

In order to address the comments and helpful suggestions from the reviewers effectively we have made significant changes not only to content but also to the structure of the document.

We have entirely rewritten the introduction to improve the description of the scope and rationale of our research as requested by reviewer 3. We also aimed to improve our description of what a multi-path representation is as suggested by reviewer 2.

The beginning of section 2 is new and includes a definition of what shared representations are and it also includes an high-level overview of research on common ground and shared context as proposed by reviewer 3. We also tried to make the description of our motivation for the use of knowledge building theory more accessible, which was commented on by reviewer 2.

Section 2 now includes a new subsection that introduces a conceptual framework for the analysis of shared representations in knowledge building activities. The reviewers expressed differing opinions on the contribution of the cognitive dimensions of notations analysis approach that we included in the initial submission. Reviewer 2 proposed to integrate related work on collaborative dimensions of shared representations instead. We found this a very fruitful proposal and integrated an analysis of collaborative dimensions that is specifically geared towards knowledge building activities. This enables us also later on in section 4 to re-examine the knowledge building concepts we introduced in section 2 - an omission that was pointed out by reviewer 1. We also think that this allows us to address concerns about the lack of analytical depth that was expressed by reviewers 1 and 3. Section 2 includes an additional paragraph in the end that describes other commercial online video editing software and the differences between those and Video Pathways.

The functional system description in section 3 was significantly shortened as proposed by reviewer 3 while the section now includes a discussion of the viewing and authoring experience to provide clarification to a comment from reviewer 2.

The term meta-information has been replaced with the more common term metadata (pointed out by reviewer 2) throughout the document.

In the introduction to section 4 the two studies are compared and the methods of data collection and analysis are described in more depth to address concerns from reviewer 3 regarding the methodology that was used for analysing the data. We merged the sections 4 and 5 into a new extended section 4 that discusses the Formative Evaluation of the Video Pathways system. The discussion about usability in this context has been significantly shortened as requested by all three reviewers. Section 4 has a new introduction with new material and an overview of the two studies followed by a rewritten section 4.1 that focuses on multi-path video creation and contains additional research data. The former section 5.2 ('Modes of Work') has been extended as requested and is now section 4.1.1. The former section 4.3 has been altered and renamed and is now 4.1.2 ('Metadata') and the former section 4.2 is now 4.1.3 ('Reusability of Video Resources'). The former section 5.1 on Cognitive dimensions of Notations has been removed and been replaced with the aforementioned new section 4.2 ('What functions of Multi-Path Video representations influenced these results?'). This discussion is couched by the aforementioned framework of collaborative dimension of multi-path video representations in knowledge building activities.

A new conclusion (now section 5) has been written that reflects on the research that was conducted and the contributions of the publication and discusses the relevance of future research on using video as shared representation. We added Table 1 as an attachment to this letter that summarises the changes to the article from section 4 onwards.

Best Regards

Ralph Barthel Shaaron Ainsworth Mike Sharples

Attachment:

Table 1: Article changes from Section 4 onwards

Passage	Changes
4- Formative Evaluation of Video Pathways - Introduction	Revised with new material
4.1 Multi-path video creation	Revised with new material followed by three subsections; 4.1.1 Modes of Work - is an extended version of the former section 5.2 4.1.2 Metadata - is an altered version of the former section 4.3 4.1.3 Reusability of Video Resources - is the former section 4.2
4.2 What functions of Multi-Path Video Representations did impact these results?	Completely new subsection that uses a framework of collaborative dimensions to analyse the results; This section replaces the former section 5.1 on Cognitve Dimensions of Notations
4.3 Discussion	New Subsection that summarises and discusses the main results of the evaluations
Passage 5.1	Removed – replaced by 4.2
Passage 5.2	Moved and slightly revised now as 4.1.1
Passage 6 Conclusion	Is now as 5 Conclusion and has been rewritten to reflect new content

*Abstract

Abstract

Online video has become established as a fundamental part of the fabric of the web; widely used by people for information sharing, learning and entertainment. We report results from a design study that explored how people interact to create shared multi-path video representations in a social video environment. The participants created multiple versions of a video by providing alternative and interchangeable scenes that formed different paths through the video content. This multi-path video approach was designed to circumvent limitations of traditionally linear video for use as a shared representation in collaborative knowledge building activities. The article describes how people created video resources in collaborative activities in two different settings. We discuss different modes of working that were observed and outline the specific challenges of using the video medium as shared representation. Finally we demonstrate how an analysis of collaborative dimensions of the shared multi-path video representation can be applied to discuss the design space and to raise the discourse about the usefulness of these representations in knowledge building environments.

Research Highlights

- describes design and evaluation of a novel system to engage creatively with online video
- enables uses of online video as shared representation for knowledge building
- discusses a framework of collaborative dimensions of shared video representations
- discusses modes of work in collaborative activities

Collaborative Knowledge Building with Shared Video Representations

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Abstract

Online video has become established as a fundamental part of the fabric of the web; widely used by people for information sharing, learning and entertainment. We report results from a design study that explored how people interact to create shared multi-path video representations in a social video environment. The participants created multiple versions of a video by providing alternative and interchangeable scenes that formed different paths through the video content. This multi-path video approach was designed to circumvent limitations of traditionally linear video for use as a shared representation in collaborative knowledge building activities. The article describes how people created video resources in collaborative activities in two different settings. We discuss different modes of working that were observed and outline the specific challenges of using the video medium as shared representation. Finally we demonstrate how an analysis of collaborative dimensions of the shared multi-path video representation can be applied to

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discuss the design space and to raise the discourse about the usefulness of these representations in knowledge building environments.

Keywords
Shared video representations, knowledge building, collaborative dimensions of shared representations, perspective taking, modes of work

1 Introduction

Online video, through its applications for entertainment, information sharing and education, has emerged as a fast-growing area of Internet usage, with young adults in particular engaging with the medium in novel and creative ways (Madden, 2007). It has been argued that the widespread use of online video offers educational opportunities and that people need to be empowered and equipped to join the public dialogues that unfold in these new media systems (Rheingold, 2007). Our research addresses this need through a design study of a tool for the creation of video knowledge resources. We describe the design, implementation and initial evaluations of a novel approach to knowledge building through the creation of multi-path video in collaborative settings. Video Pathways is a web-based system that enables people to explore alternative perspectives on a topic by collecting online video clips, then assembling these into sequences of scenes, where each scene can have one or more alternative clips. The system then enables the creators, or viewers, to form pathways through the scenes, where each path is a perspective on the topic. It could be used in formal education to examine alternative perspectives on a topic in, for example, history or science, or as a tool for informal learning through collaborative creation of knowledge.

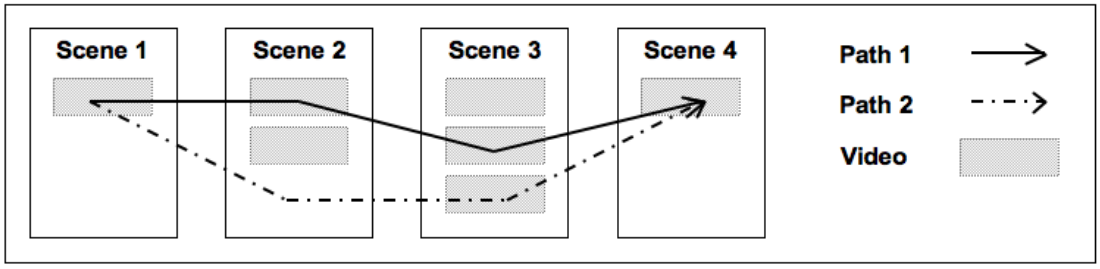

Figure 1. Schematic diagram of multi-path video

Figure 1 shows an example of the multi-path video concept. In this example, Scenes 1 and 4 each contain a single clip, while Scenes 2 and 3 contain two and three clips respectively. Pathway 1, which could for example be a video about the city of Nottingham, has been created by selecting the clip in scene 1, the first clip of scene 2, the second clip of scene 3 and the clip in scene 4. Pathway 2 comprises the same clip in scene 1, no clip from scene 2, the third clip of scene 3 and the clip from scene 4. This second pathway could show an alternative video about Nottingham that focuses on different facets of the city than the first path. Hence one can create different variations of a video from the same shared video representation. Scenes can be added, trimmed,

deleted, and reorganised. Pathways created from the scenes can be viewed and saved as linear video. The system supports collaboration by providing shared access to the clips, scenes, and pathways, and by enabling comments to be made on clips and pathways.

The research examined how people could work together and negotiate shared understanding through the activity of creating multi-path video. In this paper we first provide a background to multi-path video by comparing it to previous work on hypervideo and online video editing. Then we argue that research into tools for collaborative multi-path video is novel and timely, drawing on Knowledge Building Theory (Scardamalia & Bereiter, 1994; Scardamalia & Bereiter, 2006) as a theoretical framework. As an increasing number of people engage daily in creative problem-solving activities at their work places (Florida, 2003) the ability to create new knowledge and to innovate has become an essential 21st century skill (Bereiter & Scardamalia, 2003; Prensky, 2009). The Knowledge Building model aims to aid people in developing and refining these skills, making it an appropriate basis for our system. Lastly, we present two formative evaluations of implementations of Video Pathways: the first involving 13 students from the local postgraduate population and the second with 18 participants who collaborated remotely to create multi-path video resources. The study showed that the system was successful in enabling people to create multiple perspectives on topics through video, but usability problems and a lack of support for close real-time collaboration made it difficult to coordinate the work. We examine the findings through the lens of studying Collaborative Dimensions of multi-path video representations, which identifies issues of Modifiability, Perceived Finishedness, Discourse Management, Narrative Content, Reusability, Multiple Perspectives, Clarity and Support for Grounding.

2 Background and Related Research

Our work is concerned with the application of multi-path video as a shared representation in knowledge building activities. Suthers (2004, p.892) defines shared representations as "notations that are manipulated by more than one person during a collaborative task". Scardamalia and Bereiter (2006) propose that the central activity of knowledge building is engagement in perspective taking and collaboration, resulting in *improvable ideas*. Central to their knowledge building theory is the production of externalised representations of knowledge and the subsequent collaborative manipulation of and mutual engagement with these *epistemic artefacts* as tools to "further the advancement of knowledge" (Scardamalia & Bereiter, 2006, p.99). Stahl (2000) describes desirable functions of working with multiple perspectives in knowledge building environments (KBE) as follows:

> "A KBE with support for multiple perspectives should provide comparison perspectives, in which one can view and contrast alternative perspectives and adopt or adapt ideas from other people's perspectives. The idea of a comparison perspective is that it aggregates ideas from various individual and/or group perspectives and allows for easy comparison of them. This is an important source

> of bringing ideas together to foster convergence of thinking and sharing of insights or interpretations. "(Stahl, 2000, p. 74)

Boland and Tenkasi (1995) propose that the iterative processes of perspective making (making one's perspectives accessible to others as epistemic artefacts) and perspective taking are important dynamics of knowledge advancement.

However, the process of knowledge building is not without difficulties. It is well understood that collaborative work requires grounding of shared activities (Clark & Brennan, 1991; Baker et al., 1999; Olson & Olson, 2000). The awareness of activities of others provides context that helps people to align their contributions with those of their peers, to reach the group goals (Dourish & Bellotti, 1992). Empirical studies with knowledge building environments have further shown that effective support for discourse in knowledge building groups is a key success factor (Gilbert & Driscoll, 2002; Leng et al., 2008). Consequently, this needs to be reflected in the system design. Suthers et al. (2006) recommend that the implementation of a discourse system for knowledge building should take into consideration that textual discourse (e.g. comments, forum entries) and conceptual knowledge representations ought to be linked to each other.

2.1 Conceptual Framework for the Analysis of Shared Representations in Knowledge Building Activities

In order to assess the suitability of a shared representation to support knowledge building activities, a conceptual framework is required that takes outcomes from research on collaborative knowledge building and working with shared representations into consideration. This framework informs the analysis and interpretation of an evaluation of multi-path video as shared representation. In this section we introduce a framework of collaborative dimensions of shared representations in knowledge building activities that serves this purpose. This framework extends work on collaborative dimensions (Bresciani et al., 2008) and communicative dimensions (Hundhausen, 2005) of shared visualisations that have their origin in the Cognitive Dimensions (CD) of Notations Framework (Green, 1989).

Green (1989) described CD as a general approach to analyse information representations in interactive software environments. CD aims to examine relations between information artefacts (interactive systems and information structures, or notations) and the environment in which these artefacts are used, which together form a notational system. CDs have mainly been used either during the design stage to provide a shared language for system designers, or for the analysis of usability (Dagit et al., 2006). In the same spirit and with the same purpose, namely to provide a vocabulary for the designers of communication systems (Hundhausen, 2005), or designers of conceptual visualizations in knowledge work (Bresciani et al., 2008), the CD approach has been adapted to scenarios that center around collaborative activities. From the perspective of knowledge building theory, the use of shared representations in knowledge building environments adds further specific requirements that ought to be taken into consideration when analysing

multi-path video representations. Table 1 provides definitions of a provisional set of collaborative dimensions of shared representations in knowledge building activities that we find useful in discussing our findings. We are aware that additional dimensions can be relevant in this context. However, we suggest that these eight dimensions allow for a comprehensive analysis of knowledge building with multi-path video. The main emerging themes in the data analysis in Section 4 can be mapped to this set. Table 1 also traces the origin of these dimensions and where they or similar concepts have been discussed previously in the literature.

Table 1: Collaborative Dimensions of Shared Representation in Knowledge Building Activities

Collaborative Dimension of Shared Representation	**Definition**	**Source**
Clarity	Property of a representation to be self-explanatory and easily understandable with reduced cognitive effort	Bresciani et al. (2008)
Perceived Finishedness	Extent to which a representation resembles a final, polished product	Bresciani et al. (2008); *Provisionality* in Hundhausen (2005); *Provisionality* in Green (1989)
Modifiability	Extent to which items can be dynamically altered, constraints on the order of doing things	Bresciani et al. (2008); Hundhausen (2005); *Premature Commitment* and *Viscosity* in Green and Blackwell (1998)
Discourse Management	Control over the discussion and work flow	Bresciani et al. (2008); *Controlleability and Referenceability* in Hundhausen (2005)
Narrative Content	Extent to which the concepts of the representation can be presented in narrative form. Acknowledges that narrative is an important form of human thought and meaning making	Bruner (1996); Boland and Tenkasi (1995); *Story Content* in Hundhausen (2005)
Reusability	Extent to which people can reuse and adapt other people's contributions when creating a modification of other people's work	Stahl (2000); Scardamalia and Bereiter (2006)
Multiple Perspectives	The extent to which the shared representation enables people to create, share and compare different	Boland and Tenkasi (1995); Stahl (2000); Scardamalia & Bereiter

	perspectives	(2006); *Visibility & Juxtaposition* in Green & Blackwell (1998)
Support for Grounding	Extent to which the shared representation supports grounding in distributed work scenarios	Clark and Brennan (1991); Roschelle and Teasley (1995)

Section 4 assesses, in relation to our empirical work, how multi-path video as a shared representation is situated with respect to these dimensions. In this process we describe the dimensions in greater detail.

2.2 Video Representations and Collaborative Knowledge Building

Research on applications of video in collaborative knowledge building activities has highlighted strengths and limitations of using the video medium in this context. Strengths of video include: that it can bring an authentic context to knowledge building activities (Chambel et al., 2004; Zahn, 2003); it is a suitable way to visualize complex behaviors that are otherwise difficult to depict (Zahn et al., 2005; Hartsell & Yuen, 2006), it can be motivating (Chambel & Guimarães, 2001); it can prepare future learning (Schwartz & Hartman, 2007) and it can introduce problem situations with the help of authentic and realistic scenarios in the form of video stories (Cognition and Technology Group at Vanderbilt, 1994).

However, there are limitations and constraints in the video medium's support of effective knowledge building that include a gap between what can be effected and what is typically effected by learning from video, argued to be due to lack of active engagement with the media system (Salomon, 1994). This lack of interactivity can be overcome when people engage in the creation or co-creation of video artefacts for public or peer audiences (Burden & Kuechel, 2004; Kearney & Schuck, 2006; Levin, 2003). But, the current generation of video hosting sites are rarely used to engage in directed collaborative community activities around video resources (Halvey & Keane, 2007) due to a lack of conceptual tools that enable collaborative engagement with online video. Another limitation of video is that as a linear medium it can be difficult to depict alternative representations or enable people to compare representations (Chambel et al., 2004), which is a key requirement of successful engagement with conceptual artefacts in knowledge building activities (Scardamalia & Bereiter, 2006; Boland & Tenkasi, 1995). Chambel et al. describe this as follows:

> "However, to allow reflection, a system must have a medium that affords adding, modifying and manipulating representations, and performing comparisons. It must also afford time for reflection, elaboration, and comparison processes. Broadcast television, and most videos, are usually watched in an experiential mode, and cannot augment human reflection in this sense." (Chambel et al., 2004, p.36)

Consequently, there is a gap between the potential uses of online video in knowledge building activities and the available conceptual tools that would enable useful collaborative activities based on shared video representations. It is this gap that we are aiming to address through our research. Before Video Pathways is described - the system we developed to support this work - an overview of systems that share similarities with the proposed multi-path video environment will be presented.

As a result of technological advancements in the last two decades, and specifically informed by emerging internet technologies, hypermedia systems that enable new forms of representing and navigating through video structures have been built. Not only do these systems afford new ways to interact with the video medium but they also enable new forms of collaboration and co-creation of video artefacts. The discussion of video as part of hypermedia systems goes back to the work of Ted Nelson (1974) whose hypermedia model included "branching movies" as a vision for a new medium enabled by a hypertext system. In Nelson's understanding hypermedia is an extension of hypertext in that the hyperspace is extended to media other than text. In the 1990s, the first systems like Elastic Charles (Brøndmo & Davenport, 1989), KANE (Spiro & Jehng, 1990) and HyperCafe (Sawhneyet al., 1996) that experimented with branching movies were developed as research prototypes.

Hypercafe uses split screen technology to show different video narratives that evolve in a cafe and that play continuously while the users navigate between the different videos and therefore different narratives (Sawhney et al., 1996). For this purpose, temporal textual links are displayed next to the different video sequences that people can choose to follow. Another design idea that has been explored in a research project is Detail-on-Demand Hypervideo (Girgensohn et al., 2004). In this design approach users of the application can watch short video segments of Do-it-Yourself topics (e.g. plumbing) and are presented with possibilities to access other videos that show in more detail the different sequences of work steps (Girgensohn et al., 2004). Thus, the user interacts with a hierarchical tree structure. There are no links between different branches of the trees. This system, like the ones introduced before, used non-web technologies (e.g. Videodisc, Standalone Kiosk System) as the implementation environment. A web-based approach to support collaborative authoring of hypervideo has also been explored (Stahl et al., 2006; Zahn & Finke, 2003). The proposal to combine collaborative editing of hypervideo structures with interactive hypervideo presentations to support learning communities (Zahn & Finke, 2003) has led subsequently to the development of hypervideo design courses taught at a University (Stahl et al., 2006). However, the approach proposed by Stahl et al. required participants to have a significant amount of subject matter experience and training in order to create hypervideo resources.

Alternative approaches to collaborative video are systems that allow collaborative annotation and discussion of video (*video collaboratories*); for example, to analyse and discuss research. The Digital Interactive Exploration and Reflection (Diver) system (Pea et al., 2004; Pea & Lindgren, 2008) is a software environment that was designed for "generating different perspectives on human interaction phenomena in the form of annotated audio and video recordings*"* (Pea & Lindgren, 2008, p. 236). In Diver, people

can create their own perspective on video stories as an annotated point of view sequence (which is called a dive in the system) that, for example, analyses or highlights a certain aspect of the source video. Point of view recording means that with the help of a virtual view finder users of the system can select areas of the video and zoom in. One of the core concepts of the Diver project is to create a system that helps people to establish a common ground when they are working with video resources. Pointing to and highlighting certain areas of a video clip provides a frame of reference that can be used for discourse and meaning making in knowledge building activities that are supported through these video annotations. These annotations together with other system functions provide tools for "guided noticing" when discussing video events (Pea, 2006).

Diver provides new forms of interactions with video through a web interface that are useful to discuss video artefacts in online communities. Formative evaluation studies of the usability and effectiveness of the software with different user groups was described as positive and led to a refinement of the system over time (Pea et al., 2008). Different user-generated perspectives can be discussed with other users. However, there is no easy way to compare the perspectives of users, as they are not represented together, and it also seems difficult to repurpose the dives from other users; both of which would be helpful in knowledge building activities. Consequently, Video Pathways has a different focus from Diver as it provides an environment to create video artefacts in collaboration. The discussion about the video is done with the purpose to create new refined conceptual artefacts whereas in Diver the source video material is analysed with help of a number of tools for guided noticing. The main purpose of Diver is to support analysis of source video material, whereas for multi-path video the objective is to enable collaborative creation and modification of shared video representations.

Prior to developing Video Pathways we conducted a high-level survey of existing online video editing software to reveal possible gaps and also identify software that came close to our design idea. We used such existing software subsequently in a pilot study with a specific task as an experience prototype. The main target group for multi-path video is people without prior video editing experience, so it was of particular interest to find applications that have a relatively low entry barrier to online video editing. The search for software focused therefore on web-based video applications. We found two online video editing systems that in combination with a suitable task design had the potential to support the envisioned pilot study. These two online video services were Jumpcut, a startup that had been acquired by Yahoo!, and the online video system Eyespot. At the time of writing, both online services have now been discontinued; however recently newer commercial online video editors have been created with JayCut[2] and Movie Masher[3] that have similar characteristics to Jumpcut and Eyespot. Both Jumpcut and Eyespot enabled online video editing in a browser interface. People that used the two systems could upload and edit video clips, add effects and transitions to video and share the final product of the video editing process with others users. Both systems also enabled people to remix video that had been created by other users and to publish the

[2] http://jaycut.com/
[3] http://www.moviemasher.com

content to blogs and social video sites. Jumpcut had a few more functions than Eyespot relating to the video editing whereas Eyespot was more flexible in how the video could be shared. We judged that Eyespot provided a better user interface and organisation and it was used it in a pilot study with four participants creating video on personal fitness.

The details of the pilot study are not discussed in this paper but has been described elsewhere (Barthel et al., 2010). To summarize the main findings, it was clear there were strong limitations concerning the comparison of video artefacts and working collaboratively with different perspectives. Whilst Eyespot enabled users to *remix* other people's work, it was not possible to visualise and compare the relationship between different video sequences that people created and so making it difficult to use such systems in knowledge building activities. People also needed to upload their own video, which proved problematic in the process of our pilot since most of the participants were not comfortable with originating their own video. Finally, the pilot revealed the importance of providing a means to manage and maintain a knowledge building discourse.

3 The Video Pathways System

Informed by literature and refined by the aforementioned pilot, an initial set of design requirements for a multi-path video environment was derived. It became apparent that there is a need to support working with multiples perspectives and more specifically to provide means for lay people to create, share, compare and adopt different perspectives in a video medium. We addressed this need through the design of multi-path video representations. The system we created as a research prototype is called Video Pathways and in this section we describe the user experience of creating multi-path video with the system.

The starting point for a multi-path video structure is the creation of a movie project, typically describing the overall topic of the multi-path video representation e.g. "City Guide to Nottingham", or "How to setup a new computer". Once a movie project has been created scenes and video clips can be added to the workspace of the project. Scenes are structural elements similar to the chapters of a book and each scene acts as container for video clips. People can add a scene by clicking the 'add scene' button and giving the scene a label and a description (e.g. Nottingham at Night, or Chapter 1). Every user account of Video Pathways has a personal video clip library associated with it. This personal library consists of references to YouTube video clips. As this library is available across all projects it can consist of a diverse possibly unrelated sets of clips (e.g. humorous items, holiday destinations, hobbies, political speeches, *etc*). People can collect and add clips to this library by either copying and pasting YouTube URLs, or through a search from within Video Pathways for YouTube clips via the systems organiser. When a video clip from this personal library is dragged to a scene of a shared movie project it becomes automatically available for all other users that share this group space. Video clips can subsequently be added and removed from scenes by all users sharing the group space.

A path is a sequence of selected video clips (one or no clip from each scene of a movie project) that represents one linear way of viewing a video in a movie project. A path is thus one possible way to create a video narrative from the multi-path structure. Users of the service can select and deselect clips in scenes and create paths from the selected clips. Scenes can be omitted when building the path structure so that not every scene has to be represented with a clip in a path. The final product of the collaboration is a shared multi-path video representation from which a series of linear video paths are derived each one representing a possible narrative about the topic. So for example, the same video clips of Nottingham city centre could be used in across three different path; one that emphasizes the current architecture of Nottingham, another its history or finally practical information about transportation.

While viewing these linear paths no branching decisions are presented. All available paths are selectable in path library so that people can switch between different paths. When a path is selected the video clip elements of the path are visually highlighted in the multi-path video structure so that there is a visual indication which video clips in which scenes are part of the current narrative. Figure 2 shows a wireframe of the Video Pathways interface.

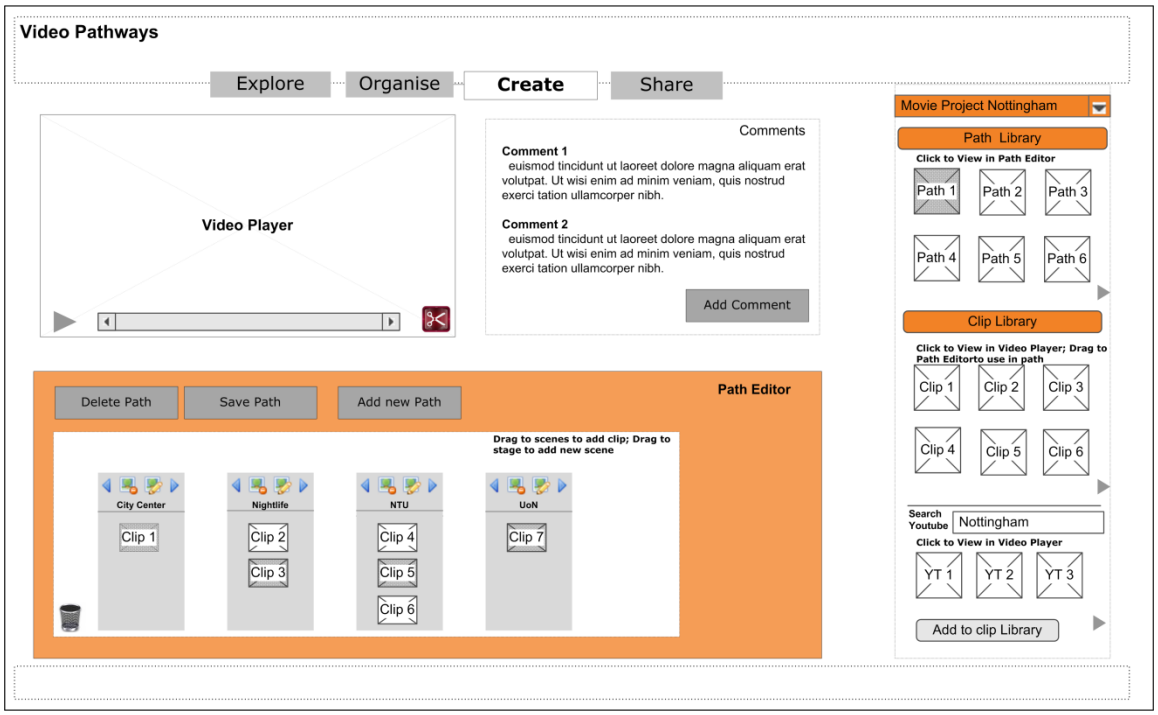

Figure 2: Wireframe of Video Pathways Interface

The system further provides a basic video editor that enables users to set the start and end point in the video stream. This is useful when people only want to use a small section from a YouTube clip and not the entire clip. Since the video is streamed via the YouTube API and limited by the constraints of the available video quality and the video content itself these *virtual edits* are sometimes an approximation as they depend on the

availability of *keyframes* in the source video. In the worst case this meant, at the time evaluations were conducted, that video would play/stop 2-3 seconds earlier/later than expected. Implications of this are discussed in section 4. Figure 3 shows the interface of the video editor in Video Pathways.

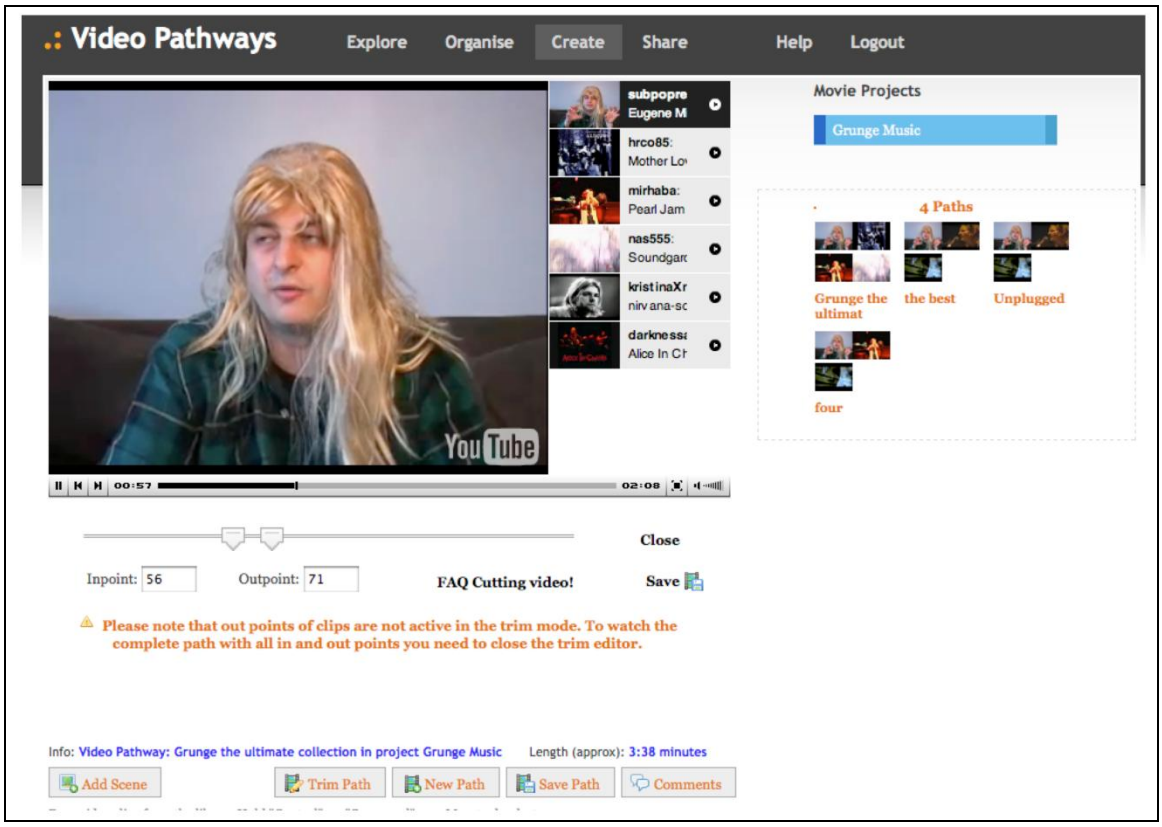

Figure 3: Create View - Video Editor

4 Formative Evaluation of Video Pathways

In order to assess the suitability of the Video Pathways prototype to mediate collaborative knowledge building activities two different formative evaluation studies were conducted. The evaluation of the system was guided by the following research questions:

- Can people effectively use Video Pathways to create multi-path video?
- Is the outcome of peoples' work successful in representing their perspective?
- What features of Video Pathways and the task designs influenced these results?

Both studies shared a number of common features. Participants worked in small groups with Video Pathways to create a group project with at least two different paths that show an alternative perspective or different aspect on a topic they were given. They also had

access to online documentation that included screencasts showing the main actions and to a PDF document describing how to use the different views of the software. However, there were also some strategic differences between the two studies designed to explore the system's features with different types of users representing different topics using alternative methods of collaboration.

In the first study, 13 participants from the local postgraduate student population in Nottingham worked together in small groups (three groups of three, one group of four). They were asked to create multi-path video resources about the town of Nottingham, their local place of study. Their task was modelled on the experience of a member of the existing student community in creating a resource to share with new or potential students of the university. Participants largely worked together while being co-located in the same physical location. A 45 minutes hands-on training in which the system was explained was administered to study participants before the intervention. Participants were given five days as a group to complete their group work. They were free to work at home but also had the option to work in a computer lab with one of the researchers present. Three of the four groups chose to at least partially work in the lab and as a result we were also able to observe some of the group activities.

This first formative evaluation comprised of a survey, a product reaction instrument and short semi-structured post intervention group interviews (15-20 minutes). The survey was designed to get a broad overview of participants' perceptions concerning different aspects of software usability, the collaboration process and their prior experiences, if any, with other online video software. In the first step of the data analysis, the results from the survey tool were analysed. The answers to the open ended questions were compared and a table was created with representative answers given by participants to these questions. A bespoke version of the Product Reaction Card Method (Benedek & Miner, 2002), described in more detail by Travis (2008) was used to evaluate desirability. Each participant was presented with a randomised wordlist of 105 different words: approximately balanced in terms of words with positive and negative connotations. The participants were asked to tick all words of the list that were in their opinion descriptive of their experience of using Video Pathways. Finally they were asked to select the five most descriptive words from all the words they ticked. This method allowed us to assess more intangible aspects of the user experience that were difficult to uncover with standard questionnaires. The group interviews were audio recorded, partially transcribed and thematically clustered (e.g. usability, collaboration, usefulness of multi-path video representations). Additionally, the researchers analysed the content that the four groups created.

In the second study, 18 participants representing industry professionals and academics (working in areas such as human-computer interaction, learning technology and mobile learning) were recruited through requests for 'Beta testers wanted for social video software' to international discussion lists for practitioners and researchers in educational technology, and on the Facebook pages for YouTube. They collaborated remotely after random assignment to one of six small groups (one group of four people; four groups of three people; and one group of two people) to create multi-path video resources that

aimed to explain the reasons for the global financial crisis of 2008, a generic subject that due to its societal implications affected many people. It was hoped that people would find the task activity meaningful, as they were likely to have experienced the consequences of the global financial crisis in some form. Video Pathways has been designed as a general social learning environment that reifies principles from collaborative knowledge building theory. In that sense, it is closer to social software systems that target a broader audience such as YouTube or Wikipedia than to software that is designed for one specific community. The system has consequently not been designed to support specific tasks for a particular community or user group and consequently there was no specific community continually involved in co-designing Video Pathways. Within these constraints great care was taken to design meaningful tasks with the awareness that how people encounter the world determines how they interpret the world (Dourish, 2001) and that this usually happens through purposeful practical tasks (Kaptelinin & Nardi, 2006). In this second study, participants worked together remotely, so that the entire collaboration had to be mediated by the system as was the initial training.

In Study 2, methods for data collection and interpretation included the analysis and visualisation of log files and interviews. The multi-path video representations were analysed as described above for Study 1. In addition, all participants were asked post their experience if they would be available for a Skype interview and nine participants agreed. A further three participants asked for an opportunity to give written feedback to interview questions so that overall detailed responses from 12 of the 18 participants were captured. These analyses were combined so that so that phenomena of interest that emerged through quantitative analysis could be followed up qualitatively in the interviews. The interview also covered a number of predefined categories that had proved relevant in the pilot study and the first formative evaluation with Video Pathways. It also flexibly explored participants' perceptions about the tool, the shared representations and the task at hand. Thus, in preparation for each individual interview or written feedback the log file profiles of each participant were revisited so that follow-up questions for example about specific usage patterns could be asked. All interview records were analysed and mind maps with relevant answers from the interviewees were drawn. The mind maps were used for structuring the contents of each individual interview and in assessing key feedback and identifying emerging themes. Key statements that were made by participants in interviews or written feedback were transcribed.

Table 2 shows a comparison of important elements of the two evaluation studies. The results of the formative evaluations are systematically discussed in the following sub sections structured by the research questions guiding the inquiry.

Table 2: Comparison of the Evaluation Studies

	Study 1	Study 2
Task	Create an introduction to Nottingham for different audiences	Create an analysis of the reasons for the global financial crisis of 2008
Participants	13 students	18 industry professionals, educators, researchers and students
Groups	Three groups of three, one group of four	One group of four, four groups of three, one group of two
Location	Co-Present	Distance
System Introduction	45 minute hands-on session and online documentation	Online documentation
Study Period	5 days	14 days
Research Instruments	Questionnaire, Product Reaction Card, Group Interviews	Log file Analysis, Interviews

4.1 Multi-Path Video Creation

In this section, the question of whether people actually did create multi-path video is addressed, along with discussion of how the participants produced them. In Study 1, video paths addressed topics such as nature sights in Nottingham, the most important annual sport events in the region and narratives about local sport celebrities. An example of the latter is a video that retraced the steps of the footballer and football manager Brian Clough in Nottingham. The path shows video highlights of his career and local places that have a link to his life. In Study 2, the multi-path video resources created included satirical views on the global financial crisis involving references to politics and resources that aim to explain some of the financial key terms (e.g. collateralised debts obligations) and the reasons that caused the financial crisis.

A general analysis of user activities in both studies showed that participants made frequent use of most relevant functions that the software provided in respect of multi-path video creation. Table 3 shows an overview of participants' activities in the two studies.

Table 3: Overview of Participants' Study Activities

	Study 1	Study 2
Groups	4	6
Video Clips	94	86
Scenes	51	36
Paths	9	23
Shortest Path (min:sec)	0:41	0:26
Longest Path (min:sec)	10:52	19:43

Participants in both studies frequently altered the length of video clips that were used in paths. The length of sequences that participants selected Study 1 were often short (e.g. 10

or 15 seconds), which suggests that re-use of video worked best in this context with short video sequences. The majority of video paths were between one minutes and three minutes in length. To illustrate this more concretely (for Study 1) Table 4 shows for the paths created, the topic of the video, the number of video clips, the number of clips edited in their length, the overall running time and the predominant underlying multi-path video structure.

Table 4: Study 1 Summary of the Multi-Path Videos

Name	Clips	Virtual Cuts	Length (min: sec)	Group	Structure (see Fig.4)
Nature	6	5	1:12	1	1
Sport	8	8	2:04	1	
Attractions	8	0	10:52	2	1
Studies	8	0	1:07	2	
Campus 1	4	0	0:41	3	2
Campus 2	4	2	6:29	3	
Culture	10	8	1:42	3	
Tourism	9	9	2:39	4	3
University	7	5	1:45	4	

Table 5 aggregates the number of paths, clips and virtual cuts, the predominant structural pattern and average path length for each of the six groups in Study 2. In the second study the paths were significantly longer on average and there were fewer virtual cuts than in Study 1. The sequences from single clips that were used as part of paths were also significantly longer than in the first study. One of the groups did not create any paths but are still included in the analysis as the three participants worked on the task and took part in the evaluation.

Table 5: Multi-path Video Creation Study 2

Group	Paths	Clips	Virtual Cuts	Avg. Length (min:sec)	Structure (see Fig.4)
1	4	6	1	3:43	1
2	4	24	8	6:50	3
3	2	7	4	13:02	3
4	0	N/A	N/A	N/A	N/A
5	8	14	7	7:29	1
6	5	13	8	6:17	3

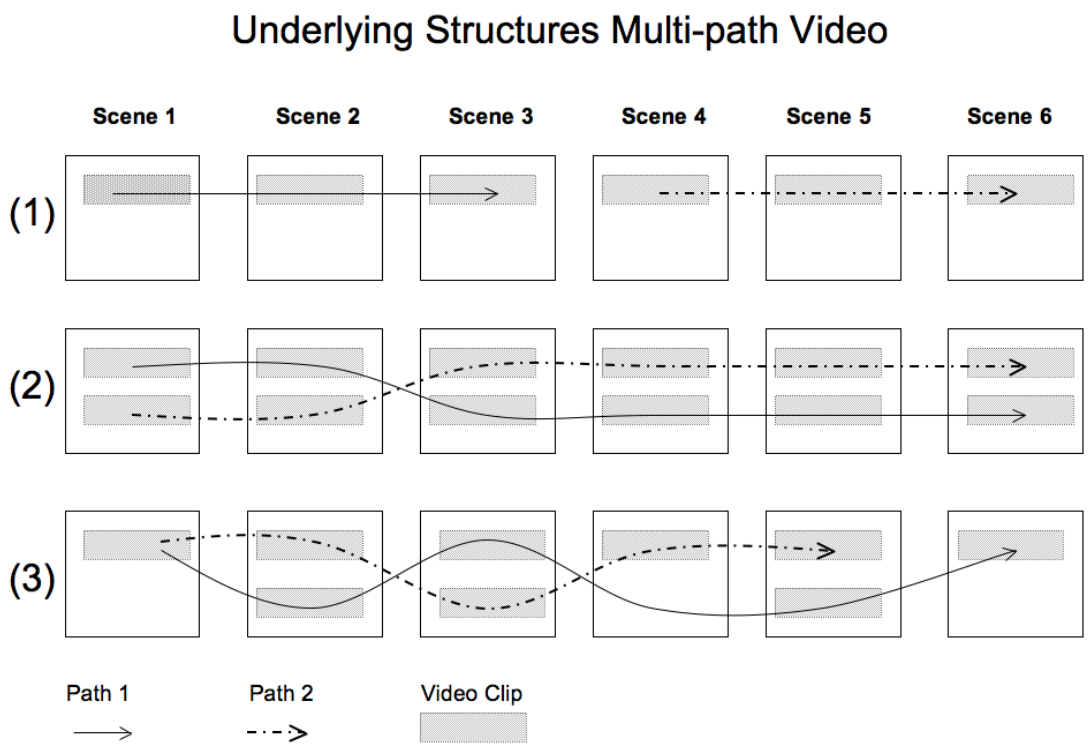

Figure 4: Possible Multi-Path Video Structures

Figure 4 illustrates the possible structures that the underlying scene and video clip from which the different paths are derived can follow. Each path can follow one of three possible patterns: (1) completely different scenes are used in each path, (2) exactly the same scenes are used, just varying the video clips of the scenes that formed the paths, or (3) an approach in which the paths are created by mixing the former two approaches such that in the multi-path structures some scenes are unique to each path, while other scenes are shared between paths and just the clips within the scenes may differ. Approach (2) could be further split up into cases where scenes show video clips that are related to each other and each one represents an alternative view of the same concept while in other cases the video clips were completely unrelated. We found that all three patterns occurred in the studies (see Tables 4 and 5) but the first and third pattern occurred more frequently. Typically, the first pattern emerged when either the task was sufficiently open ended (as in the first study) or when people expressed initially their personal perspectives but then subsequently did not get to the point of working on a joint activity collaboratively. We discuss the implications of the latter in section 4.2.

The product reaction results showed that of the 65 words that were selected (13 participants x 5) as most descriptive of Video Pathways the majority were positive with respect to both usability (e.g. ‘easy to use’, ‘simple’, ’understandable’, ‘usable’ and ‘straightforward’ and desirability (e.g. ‘creative’, ‘useful’ and ‘entertaining’). The possibility to reuse clips from YouTube was deemed as particularly desirable by most participants. No participant selected more than two words with negative association and only 7 of the 65 descriptive words that were chosen had a negative association, (‘slow’,

'stressful' or 'time-consuming'). The group interviews showed that the selection of negative words could largely be attributed to activities where people tried repeatedly to find a workaround for the lack of accuracy of the video editing function despite being made aware of this limitation of the software. The second major critique was that the system does not allow users to replace the original video sound layer. Participants felt that these functions would have helped them in making their paths more coherent and thus would have helped them in being more successful in representing their own perspectives.

4.1.1 Modes of Work

The way in which multi-path video was created by the groups varied strongly. In order to set the stage for this discussion we want to point to research on collaborative writing. It has been reported that the flow of planning, composing and revising is at the core of creative writing processes and that when people engage in collaborative writing such as in the scientific community different models of collaboration emerge. Drawing on Bass (1980), Sharples (1999) proposed three different types of team working namely sequential, parallel and reciprocal (see Figure 5).

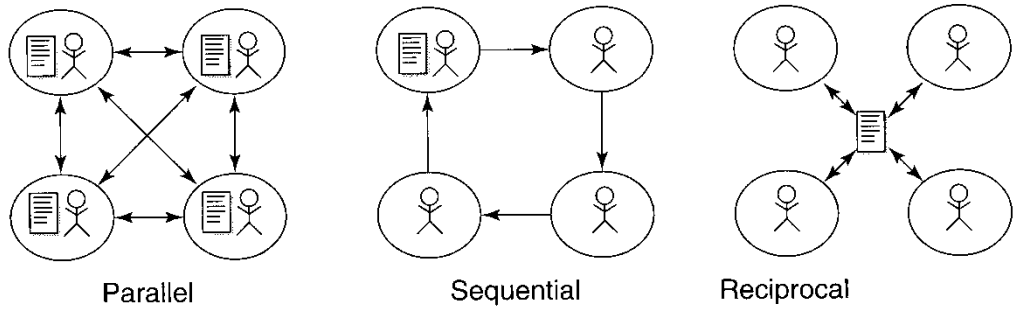

Figure 5: Types of team working for collaborative writing (Sharples, 1999, p. 171)

In the parallel work mode, people work on different sub-tasks that are part of the same overall task, in the sequential mode they work one after each other passing a product along and in the reciprocal work mode *"*all the partners work together, watching and mutually adjusting their activities to take account of each other's contribution*"* (Sharples, 1999, p.171). These work modes are not mutually exclusive and at different stages of teamwork a different approach might be used. We can compare these insights to the collaborative creation of multi-path video representations.

We observed in Study 1 that the small groups typically started using the reciprocal work mode (e.g. for planning of their project, deciding on a division of labour), and then they individually completed sub-tasks (such as looking for suitable video clips) in parallel before completing their task in the reciprocal work mode (creating the paths). Consequently, it seems important that this cycle of planning, composition and later on

revision can be supported and to some extent mediated in a multi-path video environment. Participant also affirmed in the group interviews that they had largely been able as a team to create multiple paths that they had in mind.

In Study 2, where Video Pathways mediated the entire collaboration, it proved difficult for people to create multi-path video together. We analyse in section 4.2 in greater detail how the system environment impacted these results and what would have been required to better the support in distributed scenarios. What can be said in relation to the work modes is that people did not coordinate their activities initially. What typically happened was that one participant in the group space would create a first path and then either other participants would work on a refinement of that path or more often they would create their own path sometimes only loosely related to what was already in the work space. The analysis in 4.2 as we will see is raising questions as to what extent multi-path video is perceived as a *shared representation* versus the notion of it being a *shareable representation,* at least in the first stages of a collaboration. Four of the interviewees mentioned that they wanted to create a first path on their own and share this path and then eventually refine their work through collaboration but that they had no intention to discuss what they were going to create in detail beforehand. They preferred to create a perspective of their own, then share the result of their work and discuss this result with others. This mirrors collaborative writing practises where, for example, contributors to an edited volume may create individual chapters representing their own knowledge and viewpoints, and then adjust their texts after reading the contributions of others.

4.1.2 Metadata

It is known that annotations play an important role in collaborative work settings (e.g. collaborative writing; Weng & Gennari, 2004) and it has been proposed that information about artefacts can enable or hinder reuse in collaborative design processes (Hisarciklilar & Boujut, 2007). The terms annotation and metadata in this discussion are used loosely. For the context of this discussion annotations and metadata are solely defined by their purpose in facilitating collaboration.

In Study 1 two of the four groups created multi-path video representations that were judged as more coherent compared to those of their two peer groups. They assigned scenes with semantic labels such as ‘Introduction’, ‘City Center’, ‘Castle’ so that they closely corresponded with the video narratives and the clips that were contained in a scene. Such labelling is useful as signpost to help others get an overview of what the content of a scene is about. Scenes that only appeared in one path diversified the content of the video space, whereas the use of the alternative clips of a scene for different paths showed an alternative perspective or refinement of the same concept (e.g. another part of the city centre, or a different view or aspect of Nottingham Castle). The structure of the multi-path video that consequently emerged and the process data about the collaboration of these teams indicate the beginning of interesting knowledge representations that were accessible through their metadata. In contrast, the other two groups chose more generic labels such as numbers for the scenes (1,2,3,4…) that did not reveal any of the semantics of the video narratives. This lack of useful metadata makes it difficult to easily re-use the

video paths. The content and overall purpose of the artefacts are not readily accessible when searching for them (e.g. based on title of scenes and paths).

In Study 2, there was significantly less use of metadata. Of the 36 scenes across all the groups almost two thirds (23) were not labelled and the few that were labelled had numberings of scenes so that it was unclear what the labelling would bring to the collaboration. We had hoped that people would use metadata to provide signposts about their activities in the distributed scenario but this clearly did not happen. Useful metadata seemed to be an outcome and thus an indicator of fruitful collaboration but it was not used primarily to inform others about one's own intentions.

4.1.3 Reusability of Video Resources

Another important area to explore about systems that allow reuse of video is how video clips were in fact used including the extent to which clips can be repurposed and the role of the type (length, context etc.) and origin (amateur or professional) of the video clips.

There were differences between the two studies in how people perceived opportunities to reuse clips from YouTube. There was also, depending on the nature of the source video, the impression that people felt they were sometimes re-editing something that was already the result of an editing process. In Study 1 roughly 80% of the video clips were amateur clips (e.g. short recordings of events with mobile camera, home made videos) whereas in Study 2 over 80% of the content that was used was of professional origin (e.g. TV news, documentaries about the global financial crisis). Participants in Study 2 found that deconstructing narrative video resources and building a new video by using pieces from various resources was a challenging task. This was not a contentious issue in Study 1 with its preponderance of amateur video. The paths that were created in the second study were significantly longer (see Table 5) and this seems a result of difficulties in deconstructing and reusing only small sequences of professional video content. Participants who worked with amateur video content asked for more functions for facilitating the actual video creation process but were less concerned about the deconstruction of the source video. They were more likely to express the need for additional functions (editing of the audio layer, effects and transitions between clips etc.) that would help them create refined video stories. The large majority of amateur video clips that were used were short and had no or only a little narrative structure. Hence, it seems that different types of video resources come with different needs for software support during the creation of multi-path video projects. Interestingly, a possibility to separate audio and video layers and a more robust video editing function will likely have a positive impact on both deconstruction and reuse of existing video resources.

4.2 What functions of Multi-Path Video representations influenced these results?

In Section 2 of this paper, we introduced a set of collaborative dimensions of shared representations in knowledge building activities. In this section, based on data from the formative evaluation, we analyse the properties of multi-path video representations as implemented in our research prototype in respect to these dimensions. This approach is in alignment with the original intentions of the Cognitive Dimensions framework that aimed to be a broad-brush, quick to learn, quick to apply approach that can be applied at any stage in the design process (Green & Blackwell, 1998, p. 6). The value of the Cognitive dimensions approach is also its use as discussion tool that is describing the relationship between artefact and user (Green & Petre, 1996).

Consequently, we will use the adopted framework of collaborative dimensions in the same way, to discuss strength and limitations of multi-path video representations in knowledge building activities and also to highlight some of the tradeoffs that have to be made when designing shared representations for knowledge building activities. Figure 7 shows a radar graph of our assessment of Video Pathways. The three authors agreed on a scoring for each dimension, by reflecting on data from the formative evaluation. The scoring is a heuristic approach that we found helpful to reflect on multi-path video as shared representation in knowledge building activities and discussing possible design choices. Bresciani et al. (2008) provided similar approach to discussing conceptual visualizations in collaborative knowledge work.

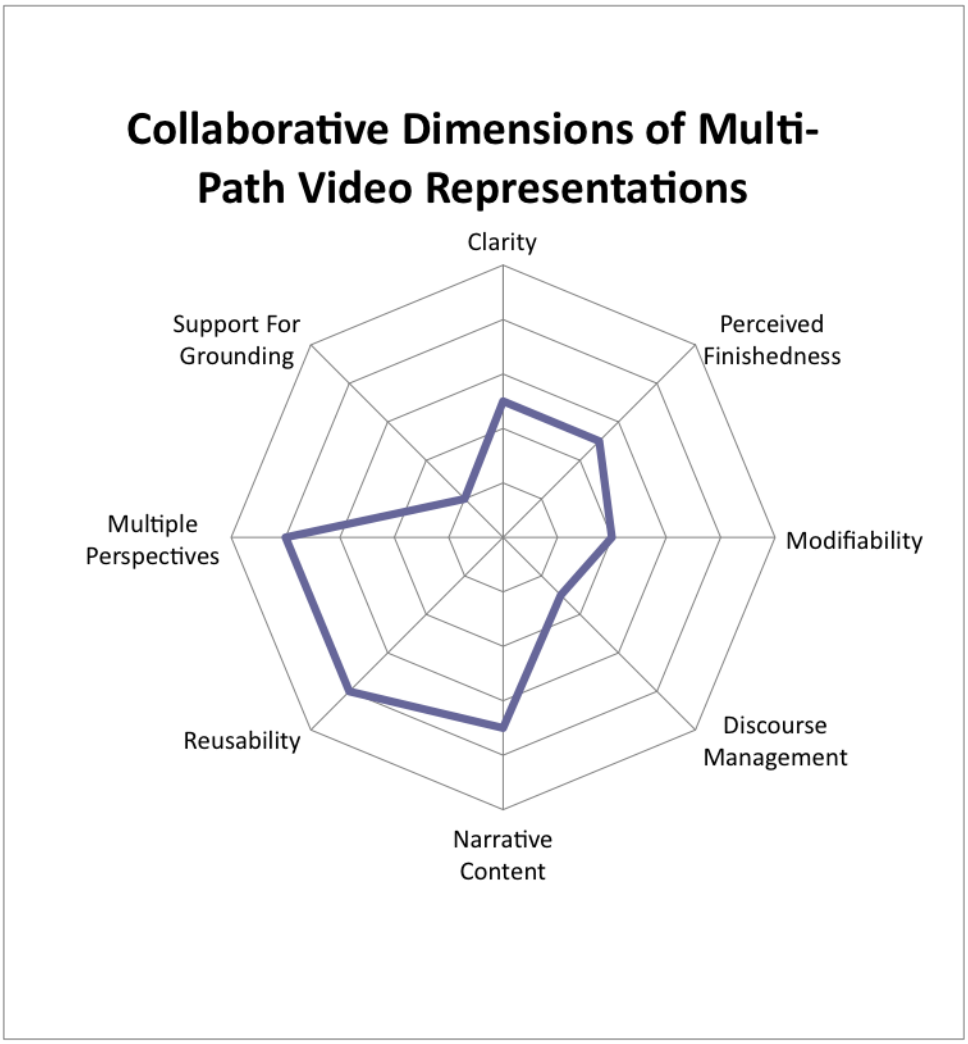

Figure 7: Collaborative Dimensions of Multi-Path Video Representations

Clarity

This dimension is concerned with the extent to which a representation is self-explanatory and can be understood with reduced cognitive effort (Breciani et al., 2008). It is also strongly related to the use of *abstractions* that can be useful or potentially harmful depending on the kind of activities people engage in a medium (Green & Blackwell, 1998). Video Pathways uses a number of abstractions such as scenes, paths and virtual cuts, and participants mentioned that these were not always clear. Below is a quote from a participant in the second evaluation that relates some of the typical difficulties some participants experienced from not having had a hands-on introduction to the system.

> *Q1:"*Sequences, clips, videos, projects – what are they? They are terms that are used indiscriminately or differently in different platforms of software."

Abstractions can be useful for modification tasks as they can reduce the necessary steps of an activity. Green and Blackwell (1998) also proposed that abstractions can be useful for i*ncremental* tasks if the abstractions fit well with the domain and if they are useful to reduce the necessary steps. In Study 1, where participants had initial training in person, the positive effect of using abstractions was visible. Participants liked the ease of use with which they could create and modify video based on YouTube clips.

Scene objects are another abstraction that was employed in the prototype. Scenes as container elements for video clips fulfil the function of making different video paths comparable, they provide means for creating alternative versions of a path and are therefore at the core of enabling multi-path video creation in the system. Approximately one third of participants in the second study had difficulties in immediately understanding the relation between clips and scenes in the system including the terminology. Scenes are however a useful part of the notation that enable working with multiple perspectives in the system, which suggests that there is a trade-off relationship between the dimensions of clarity and multiple perspectives. Our findings indicate that there is a need for either clear initial training or a better way of employing scenes as part of the overall model in terms of terminology and usability.

Perceived Finishedness

The perceived finishedness of a representation can influence to what extent people feel invited to contribute. This phenomena is also known from prototyping so that people often feel more free to comment on prototypes with a lower fidelity. The multi-path representation in Video Pathways has a relatively low-fidelity compared to professional video editing systems. The participants overall appreciated the level of fidelity of the multi-path video representations, which is documented in a number of representative statements from participants on how they would describe the prototype.

> Q2: “Its easy to learn and very efficient in creating new videos. The only thing you need to do is cutting and connecting.
> Q3:”It is a video editing software, you can just simply choose the videos online which you prefer, cut them and add them together.”
> Q4:”A very easy way of making simple videos for people who have not cut uploaded videos online before.”

A trade-off relation exists between the perceived finishedness and the modifiability of the representation. On the one hand, participants suggested that they liked the ease with which they could create video representations from YouTube clips in the prototype once they understood the system concept. But on the other hand, a number of participants also wished for many more functions in the software that potentially can get in the way of ease of use and that will increase the perceived finishedness of the representations. Since we were targeting lay people creating knowledge resources and not video editors it seems important to find a sweet spot for the perceived finishedness that encourages and not prevents people from participating. The feedback from participants seems to indicate that

Video Pathway representations are at the right level of fidelity to encourage people to participate in knowledge building activities.

Modifiability

Modifiability refers to the degree to which the items of the visualisation can be dynamically altered. This also contains an analysis of constraints on the order of doing things (*premature commitment*) and resistance to change (*viscosity*) as described by Green and Blackwell (1998).

Many participants would have liked to alter the length of clips immediately after referencing and adding them to the video clip library. In order to do this it was necessary to go to a separate view (Create view) to create and save a path sequence in a first step. Thereafter the video clips that were elements of the path could be altered in their length. Hence users were constrained in which order things could be done. This relates to the CD of *premature commitment* (constraints on the order of doing things) that has been classified as harmful by Green and Blackwell (1998) for typical activities in Video Pathways. Equally some participants did not know what to do next after referencing video clips and the necessary transition (per conceptual model) to continue to the Create view was not made or delayed. A *lookahead* was necessary in order to proceed to the next step. This 'enforced lookahead' also falls under the cognitive dimension *premature commitment*. Green and Blackwell suggest remedying usability issues that are caused by *premature commitment* by removing the constraints on the order of user actions where possible or where not to improve the situation by reducing *viscosity* of the system (Green & Blackwell, 1998, p. 23). The *viscosity* or resistance to change a video path once it is created is however rather low and fairly doable in Video Pathways. As a consequence removing the constraint on the order of things provides more room for improvement for working effectively with multi-path video representations.

Another facet of the modifiability in relation to multi-path video is the extent to which the audio layer can be altered and what function for visual effects and video editing are available. The virtual editing of the video stream worked as described depending on the source video only as an approximation, which further constraints the modifiability of the representation.

Reusability

Another important aspect of knowledge building environments is that other peoples' contributions and perspectives can be easily adopted and reused by peers in the process of negotiating meaning. The multi-path video representation was designed to enable this. However, while the reuse of path structures could be observed in both studies, instances were few due to the scale of the studies and limited collaborative interactions in the second evaluation. The discussion in 4.1.1 has highlighted that one contentious issue is if multi-path video is perceived as a *shareable* or a *shared* representation by users and if this perception changed over different stages of the collaboration. Several participants in their respective interviews seemed to differentiate between an initial stage where they

would want to share their perspective from a time when they want to collaborate with others to refine this perspective. Representative excerpts from interviews illustrate this.

> Q5: "I didn't engage in any collaboration I wasn't waiting for people to collaborate.... I would have come back and would have liked to see the ideas of others that is when for me the collaboration would have occurred."
> Q6:"At the end of it I put video usually up for my friends to see...they then usually also put videos up for me to see so that also it started as an individual activity it becomes a collaborative activity in the end."
> Q7:"I didn't really collaborate with anyone (referring to the beginning of the process)… I like the idea that I can create a pathway and then people can comment and modify it and it can grow."

This seems to indicate a desirable temporal order and preference where the sharing of an individually created video path by the participants is followed by collaboration. So in terms of our discussion of work modes, a desirable collaboration process for many with multi-path video representations starts with people working individually in parallel (parallel work mode) before people reciprocally engage with a shared representation to negotiate understandings. It is in this second phase where the aspect of reusability becomes crucial. This second stage was however, at least during the second study, rarely reached by the groups. Consequently the evaluation of reusability of components of the representations should be revisited and refined in future evaluation of multi-path video artefacts in knowledge building activities.

Discourse Management

This dimension describes if the representations enables control over the discussion and workflow. In order to support the discourse about multi-path video representations, Video Pathways includes a commenting function that linked the comments to particular elements of the multi-path video structure so that people could comment on a path as a whole or reference only single clips of a path. However, in these studies, this discourse management function was rarely used so that we cannot as yet assess its usefulness. The discourse tool has been designed based on design recommendations from prior research (Suthers, 2001; Suthers et al., 2006). In Study 1, people were largely co-located so that the discourse took place in face-to-face settings and the mediating functions of Video Pathways were not used and in Study 2, participants did not progress to this second collaborative stage (discussed in Reusability). The prototype lacked a number of additional functions that would have been useful in managing the discourse. One of the missing functions participants frequently mentioned was information or a daily digest about updates in the shared group space, an indication of other people that are online in a group space and an option to chat to them and to coordinate group actions. Representative quotes of participants of the second study in respect to discourse management are as follows:

> Q8:”I also would have liked to have a general view of what was going on….. In the perspective of using this environment to make a shared work, it would be very useful to have a summarizing view.”
> Q9:”I did not like the way I had to communicate with my peers, I preferred a forum where I could communicate with my team both synchronous and asynchronous.”

The discourse management dimension is closely related to the dimension support for grounding so that these dimensions are intertwined.

Support for Grounding

The lack of support for grounding the activities in group spaces impeded more successful use of Video Pathways in Study 2. Representative quotes from participants were as follows:

> Q10:”I did not really feel the presence of my group members. I had no idea who was logging on and who was doing what.”
> Q11:”We are just inferring what the other person is trying to say through a video but we don’t know.... so there is a lot of inference and it might be ambiguous”

In the first study this limitation was not relevant since people worked mainly while being co-located so that common ground was established in face-to-face discussions. Before further use in remote settings the prototype ought to be updated to include a more complete feature set that can help people to establish common ground. The participants in particular suggested that they would have liked opportunities to connect with other peers on the platform to get general advice and to coordinate collaborative activities (e.g. through a forum).

Although we were not unaware of the likely importance of grounding we decided against including a general forum and a complete set of community functions before our evaluations for several reasons. The first is that we were keen to explore if the commenting system in combination with annotations would be sufficient to mediate the collaborative creation of multi-path video representations. A second reason is that we wanted to keep the annotations and comments on the video paths linked to the artefact that people collaboratively created as outlined in the previous section. Finally, within the constraints of our research it would have been a daunting task to develop Video Pathways into a feature complete social software site.

Narrative Content

This dimension assesses to what extent a representation supports the use of narrative when creating knowledge resources. Boland and Tenkasi (1995) contend that the narrative mode of thought (Bruner, 1986) has a special role to play in knowledge advancement but is underrepresented in communication systems that mediate perspective taking and perspective making in knowledge communities. Hence, they propose that

narrative should be emphasised and employed more widely in systems that aim to support perspective taking in knowledge work. Referring to functions of narrative, Olson (1990) proposed that narrative acts as a framework to make events comprehensible, memorable and communicable. Hence narrative has in relation to knowledge representation two core functions or sides. It is used for knowledge telling but also for constructing new knowledge (Abbott, 2002). The nature of video content is narrative so that multi-path video representations are suitable to support these processes. People create their perspective as narrative video paths and they engage with other people's perspectives that are equally presented in narrative form. However, our discussion in section 4.1.3 has already highlighted that the reuse of parts of narrative is not trivial and that a comprehensive set functions is required to support creative applications of the video medium. Our discussion also pointed the current constraints of the prototype system in respect to its video editing functions and its limitations.

Multiple Perspectives

We have argued that the creation, comparison and sharing of different perspectives through cognitive artefacts is crucial in knowledge building activities. This dimension directly addresses this requirement. This requirement is also related to the dimension of *visibility and juxtaposition,* which Green and Blackwell (1998) described as the ability to find, view and compare components.

The multi-path video representations in Video Pathways overcome a main constraint for effective uses of video for knowledge exploration as it makes different perspectives visible and comparable. In Video Pathways, scenes (an abstraction) are used to enable this comparison. The discussion has already highlighted the trade-off relationship between the dimension of clarity and multiple perspectives in Video Pathways. The ability to work with multiple perspectives is central to effective knowledge building. Consequently, we argue that scenes as abstractions are important enablers and that their advantages for multi-path video creation outweigh problems of conceptual complexity. One main contribution of this research is therefore that it enables novel ways to engage with different perspectives in a video medium and thus overcomes a serious limitation for use of video in knowledge building activities.

4.3 Discussion

This paper concludes by revisiting the three research questions that guided the evaluation. Through the studies, we assessed the first question *if people can effectively use Video Pathways to create multi-path video*. Our findings, especially from the first study, suggest that the multi-path video created by participants could be suitable as knowledge representations in everyday learning activities. In the second study participants were less successful in so doing as they lacked a formal introduction to the system. Furthermore, there were insufficient functions to support grounding of the collaboration and to manage a discourse centered on multi-path video and this also prevented many people from using the prototype effectively. In this distributed setting, we also found indicators that people

initially perceive multi-path video rather as a sharable than a shared representation. Consequently a design recommendation is that a useful knowledge building system that supports distributed scenarios of collaboration needs to be able to mediate this transition between a parallel mode of work where people create paths individually and reciprocal collaborative interactions during the creation process.

A second question is *if the outcome of peoples work is successful in representing in their perspectives*. There a number of factors that impact upon whether participants felt that this was the case or not. In the second study, 5 of the 13 participants did not create their own path largely due to usability issues. The content and narrative of the source video that people are trying to repurpose is also relevant in this context. Participants found it in particularly difficult to deconstruct professional video material given some of the technical limitations that determined how the video could be reused (e.g. virtual cutting as approximation, no separation of the audio layer). In contrast, participants in Study 1, which used largely unedited amateur content, were excited about the possibility to easily join together different YouTube videos and found the software highly desirable as the system enabled them to tell the stories they want to tell. Consequently, it could be concluded that the created multi-path video was partially successful in representing peoples' perspectives. However, in knowledge building activities the creation of a perspective is only an initial step. Subsequently through the comparison of different perspectives, idea refinement and convergent thinking an adaptation of perspectives take place so that new group perspectives emerge as a result of this. It is a limitation of our research that this stage was not reached and could not be studied in distributed settings.

Finally, we asked *what features of Video Pathways and the task designs influenced these results*. For this analysis we used a framework of collaborative dimensions to describe multi-path video representations as presented through the Video Pathway prototype. The results showed that multi-path creation with the current prototype and especially coordination between participants was only effective in a co-located setting where people grounded and coordinated their activities through face-to-face interaction. In distributed setting functions such as (group) forums, chat, email notifications would have been needed to support planning and coordination between participants. Consequently, a multi-path video environment ought to support these functions that are essential for distributed collaborative knowledge building activities. Our analysis also highlighted that there is a tradeoff relationship between enabling working with multiple perspectives and the clarity of shared multi-path video representations. In order to enable the comparison of different perspectives and the reuse of path sequences a number of abstractions (most notably scenes) are employed. While these abstractions are useful to work effectively with multiple perspectives this comes at the cost of a reduced clarity of the representation which makes it initially harder to learn the system through exploration. Furthermore, our findings have highlighted that the reusability of other peoples' contributions might mainly be useful at later stages in collaborative knowledge building activities with multi-path video after sharing an individual perspective on the topic at hand. In terms of the modifiability of multi-path video resources, it showed that the approximation as provided through virtual cuts and the lack of a separate audio layer proved problematic depending

on the scenario. Possible future iterations of a multi-path video environment should therefore include a more comprehensive set of online video editing functions.

5 Conclusions

Video Pathways was designed as a conceptual tool to enable novel forms of collaborative and creative engagement with online video. We explored the usefulness of multi-path video as a representation in informal knowledge building activities in two different settings. These empirical studies provided a background for a rich account of how people used the system to create shared video representations. The results show that the system enabled people to represent their perspectives through multi-path video in co-located settings and was perceived as desirable by study participants. However, our research also showed that the system lacks important functions to support grounding and discourse management of collaborative activities, which limits its usefulness in distributed settings. We discussed what is needed in future design iterations to overcome these constraints such that an assessment of the educational effectiveness of using shared multi-path video representations in collaborative knowledge building activities can be performed.

This article also presented an analysis of the collaborative dimensions of shared multi-path video representations in knowledge building activities. The approach we used for this analysis has its origin in the Cognitive Dimension of Notations framework and adds new insights about the affordances of shared representations when used in activities that are specifically geared towards knowledge building. We found the analysis of collaborative dimensions a useful way to encourage discourse about the design of shared artefacts in collaborative knowledge building environments. We provided an example of an analysis of collaborative dimensions that unpacked these processes and that showed some of the trade-off relations that exist in this context. Consequently, we see collaborative dimensions as a valuable tool to unpack this design space and to discuss these dimensions during the design process and in the evaluation of knowledge building systems. The application of this framework is relatively easy to learn and can flexibly be adapted to other contexts. This is not to say that the dimensions we used are complete or ought to be exactly reused in the same way we applied them in our research. However, they represent dimensions that we think are particularly useful for the design of collaborative knowledge building systems.

Potential uses of online video for everyday learning and knowledge building activities in online communities have become widespread but the full potential of engaging with ubiquitous video resources remains so far largely untapped. Novel applications and user interfaces for engaging with social online video such as tablet computers, smartphones with advanced integrated video recording capabilities and computing applications that allow seamless sharing of video media are gaining further ground. De facto standards such as HTML5 ensure that online video continues to be a fundamental fabric of the web that can now also be increasingly accessed in the home through *Smart TVs*. Consequently an argument can be made that a design study that uses tactics to create and understand a social video environment for working with shared representation is a timely intervention.

Our research outlined how additional opportunities for knowledge building with video can be created that overcome limitations of current models of interaction with video resources in collaborative activities. We hope that our intervention provides new insights that can stimulate the discourse about using the video medium as shared representation for everyday knowledge building.

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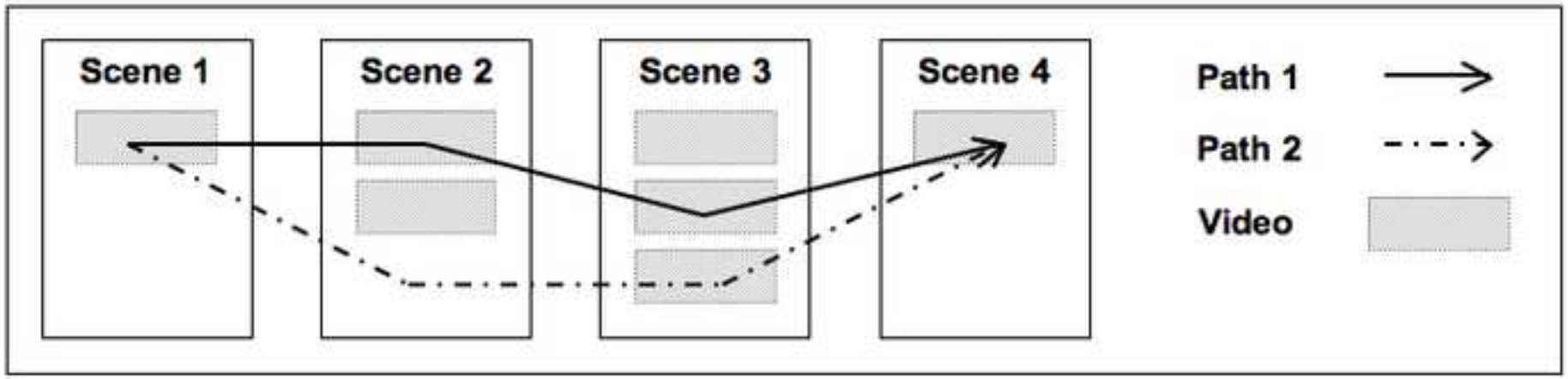

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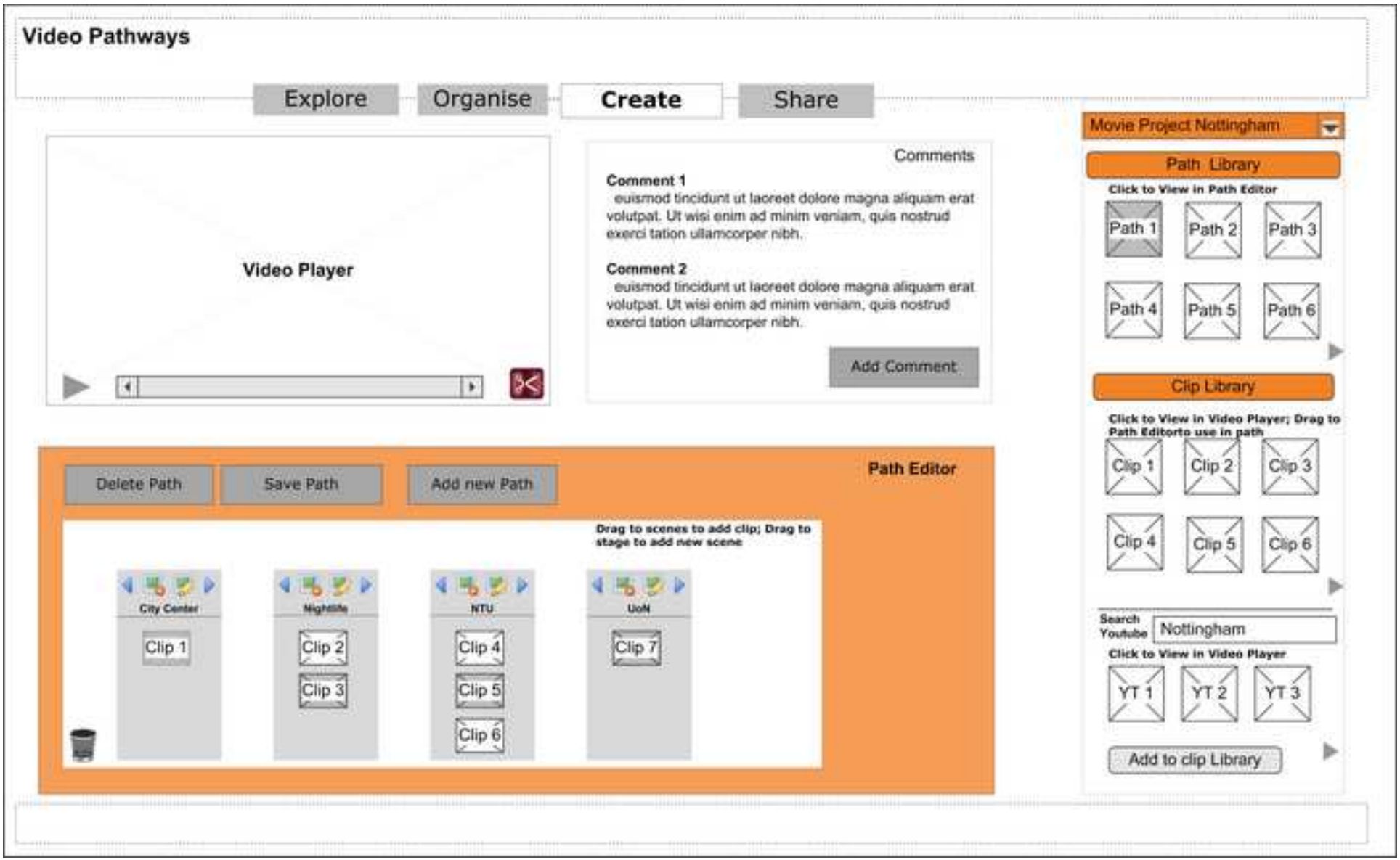

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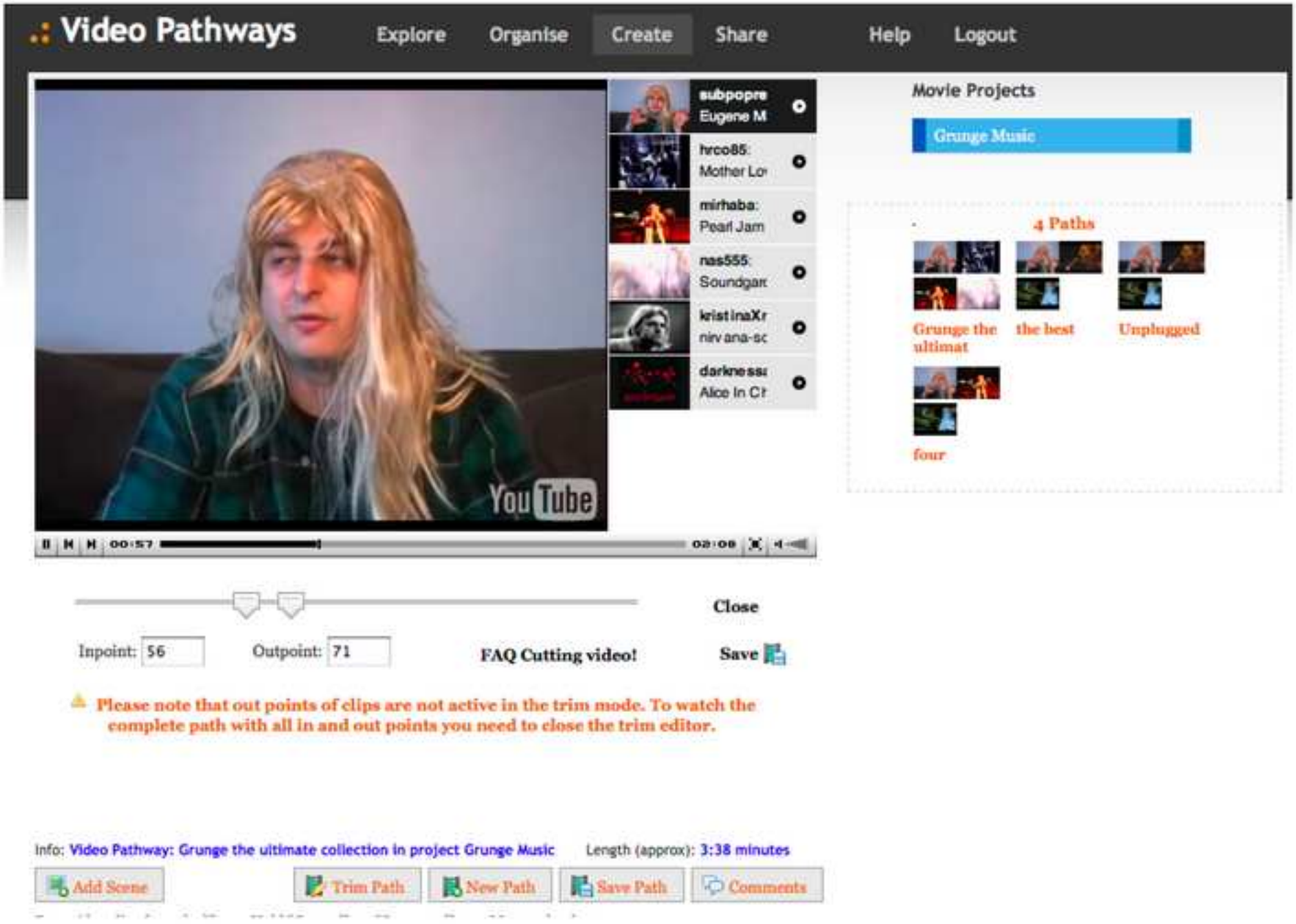

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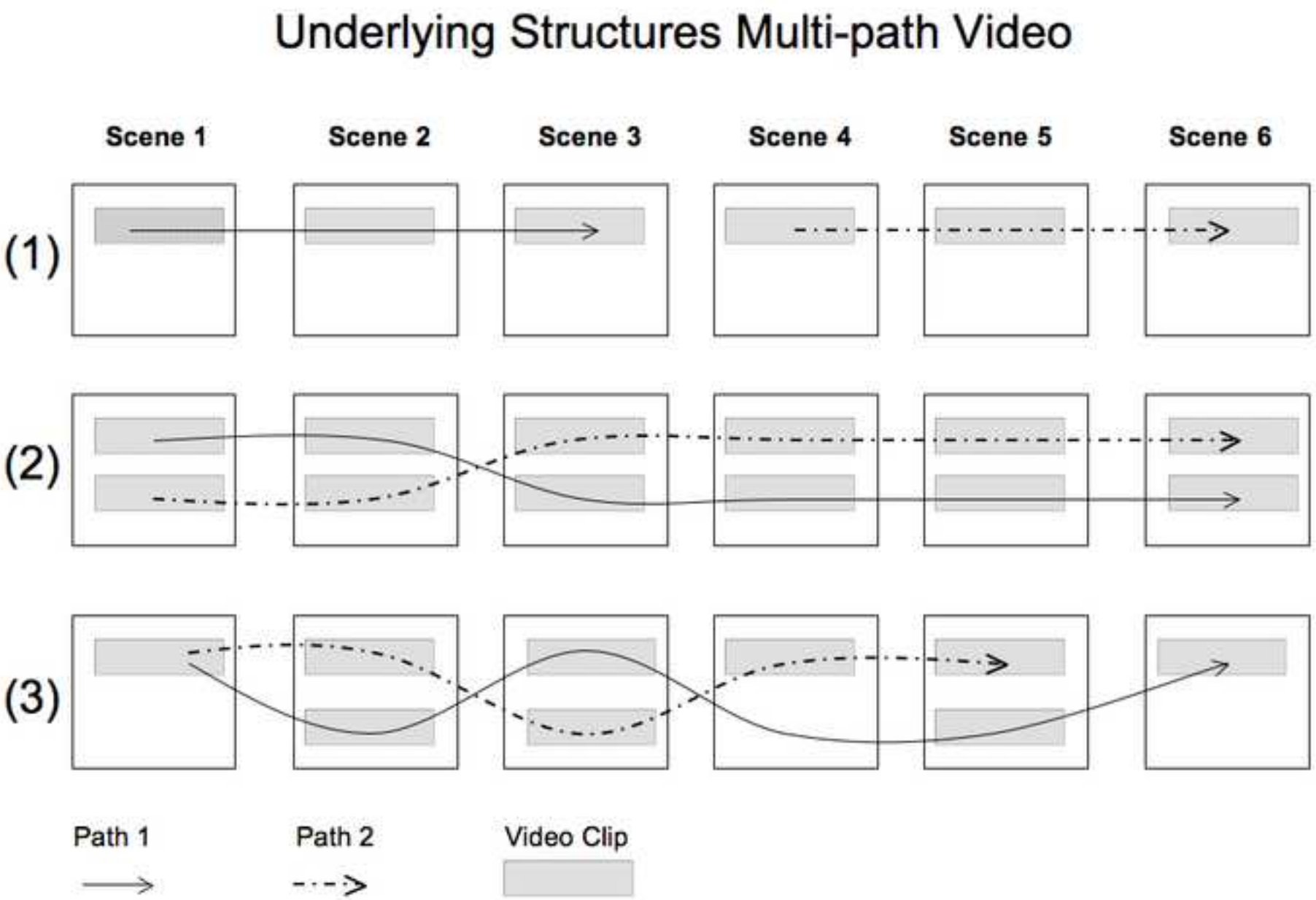

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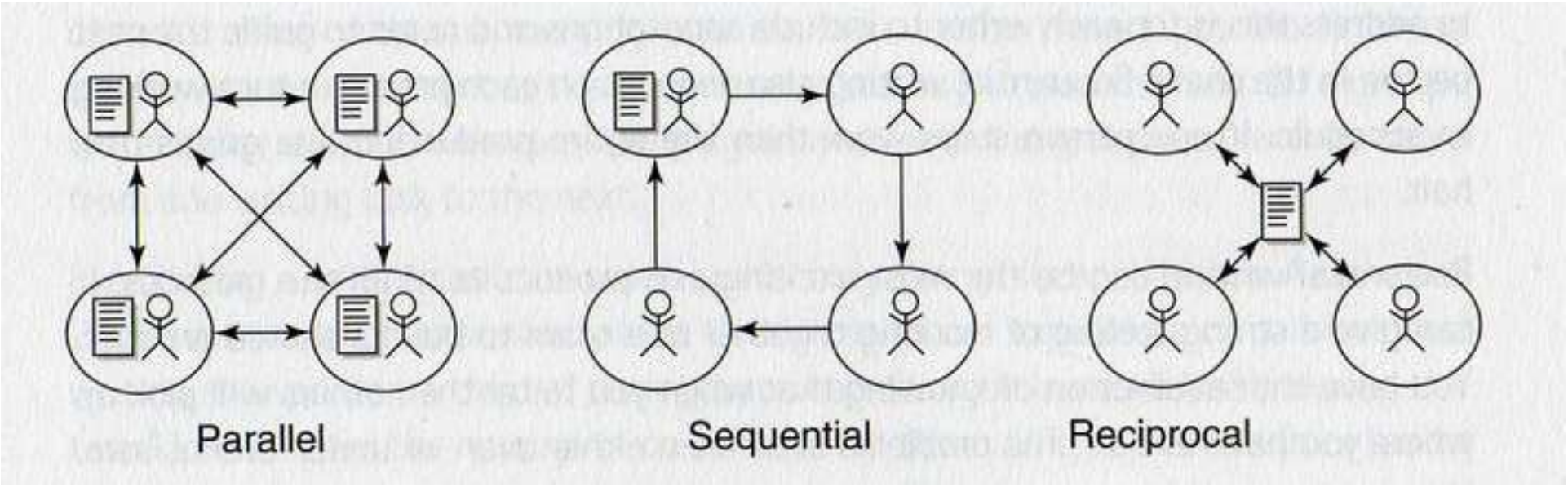

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